New railway lines are being built in almost every country, the existing lines get improved or double-tracked and traffic gets denser everywhere. This makes it important that the operational performance of a track and signalling layout can be fully understood, not only by railway operators, but also by the supplying industry.

Computer simulation of railway operations offers the most comprehensive way to study the rail systems and operations in detail, even if the railways do not yet exist, the rolling stock is not available, or the daily operations do not allow access.

In this article I would like to describe the benefits of simulation, the principles of doing a simulation and what output can be expected.

**History**
Since the late 1990s European railway operators and the supplying industry in Europe started using simulation more and more as a tool to improve operations and verify track layout and signalling design. The railway simulation software “OpenTrack” which is used and described in this article started in the mid-1990s as a research project at the Swiss Federal Institute of Technology.

Today, the railway simulation tool OpenTrack is a well established railway planning software and it is used by railways, the railway supply industry, consultancies and universities. The tool is continuously improved until now to comply with the latest trends, developments and standards. It is used for all different types of railways, for example, but not limited to mainline, MRT, LRT, Trams, High Speed and Maglev. Continuous development allows the latest systems and operational approaches to be simulated.

The software runs on any standard PC or Mac with up to date specification. Systematical use of simulation started in Europe, but now simulation is used by operators, supplying industry and planners all over the world.

**Use and benefits of a simulation**
OpenTrack is a very flexible tool; it fulfils the needs of operators, suppliers and planning units. It is independent of the product or system specification. The software supports the following tasks:
- Determining the requirements for a railway network’s infrastructure
- Analysing the capacity of lines and stations
- Rolling stock studies (e.g. future requirements)
- Running and Headway time calculation
- Timetable construction and verification
- Analysing the robustness of timetables (single or multiple simulation runs)
- Bottleneck solving
- Prepare reduced service scenarios (e.g. line closures for maintenance)
- Analysing the effects of system failures (such as infrastructure or train failures) and delays
- Evaluating and designing various signalling systems and/or ATP systems, such as discrete block systems, short blocks, moving blocks, LZB, CBTC (communication-based train control), ATP, ATO, or different ETCS Levels
- Calculation of power and energy consumption of train services
- Analysing the contractual requirements and prove of compliance
- Feasibility studies for line extension projects

**Running a typical simulation**
For an accurate simulation track layout (incl. line speeds, gradients and curve radius), signalling information (e.g. location of signals, turnouts and ATP transponders) and rolling stock data is needed. Based on this information a simulation model of line and rolling stock is built up. Operational information like timetable (proposal), routing and dispatching information has to be added to start the simulation.

During the simulation the running activities will be displayed in graphical animation, data output will be logged in the respective log files and graphically displayed on the screens. In an interactive process input data will be modified (e.g. timetable updated or signal positions modified) until the simulation shows the required results. Often a slow motion simulation will be needed to clearly show the detailed sequence of events. The final simulation output will be in graphical and tabular data. The simulation software allows many options of output to be produced.

**Time way diagram**
A time way diagram shows train operation on a specific section of the line. Trains of different categories may be displayed in...
signalling and shorter signal distance, including CBTC, are
achieve the needed safety. Modern signalling systems with Cab
mated train operation systems overlay the signalling systems to
Modern ATP systems and an increasing number of fully auto-
Scenarios and delays
The possibility of adding random delays to trains allows
studying operations in different situations than the ideal
scenario. Random delays can be added to trains in general or
just on specific sections. Delays can be added for running
times or for dwell times. This feature together with the possibil-
ity to run a simulation multiple times, with statistical variations of
delays, allows evaluation on the timetable stability.
Different ATP systems
Modern ATP systems and an increasing number of fully auto-
ated train operation systems overlay the signalling systems to
achieve the needed safety. Modern signalling systems with Cab
signalling and shorter signal distance, including CBTC, are
widely used. All these systems have their impact on operations.
The simulation system caters for all these systems and takes
into account its parameters; this allows verifying the design of
these systems (e.g. including transponder location) and the
impact on operations. In early conceptual stages of a new railway project,
simulations with different ATP systems may help to evaluate the
best suitable system (unless international standards require a
specific system).

Simulation projects
There are many reasons to do a simulation. Depending on the
type of organisation, different aspects of the track/signalling
layout – rolling stock – operations interface may be under
investigation.
Typical simulation tasks for operators are detailed
investigations of impacts on timetable caused by changes on
the system. Usually only a limited section of the system is investi-
gated, in particular sections with lines crossing each other or in
terminal stations where trains are changing directions. In these
locations sometimes seconds saved on a route release may
have a big impact on the timetable and its operational stability.
Timetables scenarios for reduced service periods e.g.
due to a line closure for maintenance can be tested in advance.
Revised time table derived from the simulation can be preloaded
into the traffic management system and allow smooth opera-
tions during such periods.
When line capacity reaches its limits changes on the
infrastructure may be needed to increase the capacity. Any
change of infrastructure always comes with a cost consideration.
Simulation of different improvement scenarios allows verifying the
best solution. This allows minimising the construction efforts. A
smaller solution particularly designed to cater for the planned
services saves cost and ensures uninterrupted service.

Large scale simulation projects
Railway networks of large cities often consist of a complex
mash of lines. Lines cross or jointly use sections of track. With
short train intervals on all the lines simulation is often the only
way to see the limits of a timetable. In several big cities simula-
tions have been performed to evaluate the new timetables. This
includes running different timetable proposals and verifying their
stability by running them hundreds of times with statistical
delays imposed.

Small and simple simulations
Not every simulation has to be a large scale simulation study
that needs a big budget. In many cases a simple simulation can
give the answers needed. Very often such simulations can be
done with simplified data input. A graphical output of a simulation
may already be enough to solve the question without giving the
need of a long report.
At the beginning of a big construction project only
limited data might be available to run a simulation, but with
regards to the stage of the project this is often enough to verify the
early design. At a later stage the data may be brought up-to-
date with more details, without having to start from scratch.

Conclusion
A simulation might look like a big task (and cost) at the begin-
ing. The resulting output, its accuracy and the impact of
understanding operational behaviour of a line and proper
verification of data will deliver a pay back for all earlier efforts.
If a simulation model is built up early during a project it can be
used throughout all the stages of building a railway line and
during operations. Once simulation data is ready, further
simulation for subsequent tasks can easily be done and needs
considerably less time. Computer based railway simulation is a
proven and accepted method in planning and verification of
railway construction and railway operation.

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